QC 852
.H3
~~445~~
~~118~~

Presented at U.S. Army Electronics [illegible] Conference on [illegible] May 14-15, 1964

CLIMATOLOGICAL AIDS TO TROPICAL ANALYSIS AND FORECASTING

William H. Haggard, Georgia C. Whiting
and
Russell L. Durham

National Weather Records Center
U. S. Weather Bureau

The preliminary report is presented on some synoptic climatological investigations of mid-latitude upper air patterns associated with tropical cyclogenesis in the western Caribbean, Gulf of Mexico, and eastern North Pacific.

Storm tracks of North Atlantic and eastern North Pacific for the period 1947-1963 are related to the normal 500 mb. subtropical ridge, and some comments are offered on the relationships between storm tracks and tropospheric flow patterns.

A number of specific proposals are offered for climatological investigations designed to assist the tropical analyst and forecaster.

The tropical analyst and forecaster is confronted with several obstacles in the detection and prediction of tropical storms. Large areas devoid of data, intricate patterns and the small variability of many meteorological parameters all combine to make his task difficult. This is compounded by a lack of general knowledge as to the significance of departures from mean values of observed meteorological data. Many studies have been made of the normal paths or most frequent paths of tropical storms originating in or passing through selected geographic areas. In more recent years, increasing attention has been placed on the variations within the season of the most probable paths of storms, as well as the most probable locations of their first appearance.

In Weather Bureau Technical Paper No. 36, North Atlantic Tropical Cyclones, Mr. Cry, Mr. White, and I attempted to summarize the available knowledge on the tracks and intensities of North Atlantic storms and hurricanes occurring in the years 1886-1958. These data have been used by a number of researchers in seeking answers to such questions as when and where do storms originate; where do they go from there; what is the probability that the storm at any point in any given time and space will strike a given section of coastline within various specified time intervals; are there secular trends to tropical storm and hurricane activity; and many related questions.

At the Third Technical Conference on Hurricanes and Tropical Storms held in Mexico City in June 1963, several papers were presented dealing with the climatology of tropical cyclone activity. At that conference, I showed a number of preliminary slides dealing with climatological-synoptic patterns associated with North Atlantic tropical cyclogenesis. These illustrated patterns apparently related to tropical cyclogenesis within limited time and space regions. Figure (1) shows two composite charts developed by combining the five individual daily charts for selected days in June on which tropical cyclones were first detected over a limited area in the Gulf of Mexico. These two composite charts, sea level in the lower right and 500 mb. in the upper right, are compared with the June average sea-level pressure in the lower left and the average June 500 mb. height and temperature in the upper left.

The sea-level composite chart is characterized by an intrusion of high pressure over the Great Lakes area, a deep low over eastern Canada and northern New England, and a northward shift of the ridge of high pressure over the eastern United States.

The composite 500 mb. chart is characterized by the appearance of a closed high center over the southwestern United States, a ridge of high pressure extending east-west north of the Gulf Coast, and an easterly flow at the 500 mb. level over the entire Gulf of Mexico.

In a separate investigation, Mr. Oliver M. Davis has suggested that the probability of hurricane or tropical storm formation may be evidenced by repeated patterns in the upper air or at the surface or a combination of both preceeding storm formation. He has suggested that these patterns, when established and described, may be used for forecasting the possibility of storm formation.

He has suggested that as much as one or two weeks prior to storm formation an intense low is formed over eastern Canada, and has described several related pattern changes.

Certainly, the composite chart shown in this slide, which was arrived at quite empirically by picking days which had as their common feature the appearance of a storm in the southwest Gulf of Mexico in June, suggests that his hypothesis of a cold low over eastern Canada is, in this instance at least, supported.

Most previous studies of tropical cyclogenesis and movement have concerned themselves primarily with the storms in specific geographic areas, especially the western North Atlantic, the western Pacific and the Indian Ocean. From time to time, some attention has been devoted to storms in the eastern North Pacific. Since the majority of these form and move through areas of sparse data coverage and only occasionally directly affect populous land areas, these storms have not been given especial attention until recently.

On the back of the Pilot Chart of the North Pacific Ocean for April 1964, Mr. Hans E. Rosendal of the Office of Climatology of the U. S. Weather Bureau, has an article published under the title, "Eastern North Pacific Tropical Cyclones 1947-1963."

I have been impressed with the fact that we have a most unique situation in the Americas in that the atmospheric circulation of the western Atlantic Ocean overruns the land connection between the North American and South American continents and that the West Indies-Central American land complex happens to occupy the area in which the circulation would be most favorable for the development and travel of tropical cyclones. Therefore, I feel that it is worthwhile to look at the tropical cyclones of the North Atlantic Ocean and eastern North Pacific Ocean as all members of the same family. Accordingly, a group of us at the National Weather Records Center have reproduced the annual tropical storm tracks for the years 1947-1963 on a map base which permits the portrayal of these two groups of storms together on a single chart. We have used the North Atlantic storm tracks from Technical Paper No. 36 and subsequent annual issues of Climatological Data, National Summary, and have used Mr. Rosendal's tracks of eastern North Pacific storms.

Figures (2) through (9) show these tracks for the principal portions of the hurricane season. In figure (2), tracks for May 1947-1963 are shown, together with the mean 500 mb. 19,300 ft. contour taken from the Atlas of 500 Mb. Wind Characteristics for the Northern Hemisphere, by James F. Lahey, Reid A. Bryson, Eberhard W. Wahl, Lyle H. Horn, and Vilas D. Henderson, published by the University of Wisconsin in 1958. The probable position of the 500 mb. ridge line is also shown as a heavy dashed line. The majority of May storms have essentially a northward travel, though many seem to go through a series of convolutions in their attempts to migrate.

In figure (3) the storm tracks for June are shown, together with the ridge line and the 19,300 ft. mean contour. June storm origins are more prevalent west of Central America than to the east, and one cannot help but be impressed with the fact that the storms from the Gulf move north or northeast, while the storms originating in the Pacific have their origins at lower latitudes and show a much stronger tendency to migrate to the northwest.

In figure (4) we see the storm tracks for July for these years, and again the 500 mb. mean ridge line and the 19,300 ft. contour. 19,400 ft. contours have been added to this map over the southwestern United States and western North Atlantic. In the Gulf of Mexico, the ridge line has migrated 3-4° of latitude northward. The storm origins of the west coast of Central America cover a larger area and there are more of them. The tracks from the Gulf of Mexico are rather similar still to those of June, and a few tracks appear in the North Atlantic.

Figure (5) shows tracks for the month of August for the 17 years we are considering here. The high over the southwestern United States is not as intense; the ridge line in the Gulf is in approximately the same latitude as it was in July, though it has swung to a more east-west orientation; and the 19,400 ft. contour over the Atlantic is not greatly changed between these two months. There certainly is a remarkable change in the storm origins and their primary movements. The frequency of storms over the eastern North Pacific is reduced between the months of July and August, while the frequency over the North Atlantic is greatly increased.

At this point, I would like to digress for a moment and suggest that the mean monthly pattern is not the appropriate pattern to describe storm origin and movement. If one makes the hypothesis that storm origin and movements are, in fact, closely related to the mean tropospheric flow pattern, they can make several inferences about those patterns, and the mean patterns shown on this series of figures may differ somewhat from the patterns that our group, at least, would infer. Pausing with August to look at this specific item, one would get the impression that storms occur when the high center over the North Atlantic is somewhat to the east of the position shown on this mean chart and that the storms recurve at about longitudes 70° to 80°W. through a somewhat deeper trough than shown on the mean pattern.

In September--which is broken into two parts following the custom of many prior authors because of the total confusion of lines created by attempting to show all September tracks on a single map--we see first the storms for the first half of September on figure (6). Here in the first half of September, we have more storms in the eastern North Pacific in these 17 half months than we did in the 17 full Augusts we have just used. Two families of storms appear in the Gulf--those which occur well south of the mean ridge line and move westward and those which occur in the mid and north Gulf and move northeastward. Very few storms move through the central Caribbean. Many which originate over the North Atlantic move up well offshore in a rather limited path width past Bermuda.

The combinations of many of the early September storms would suggest in the mean tropospheric flow pattern one might infer that the ridge line at the time of storm passage is in the vicinity of the loop on the path. The mean ridge line is well south of the locus of these loops. One might guess from this that storms are more likely to occur when the 500 mb. ridge is somewhat north of its mean position. Certainly this is not an original thought.

The last half of September is shown in figure (7). It, too, has many wobbles and loops on the storm tracks. Those over the North Atlantic are north of the mean ridge position, while those in the vicinity of Cuba or in the Gulf of Mexico are near or south of the mean ridge position. Fewer storms occur in this half of September over the eastern half of the North Pacific, and their path suggests that the mean ridge line might be even further south during their occurrence.

In figure (8) the October tracks are shown. In many respects they look like a mixture of May, June, July, and early August storms rather than like late August and September storms. The subtropical high at 500 mb. is at its lowest height and has moved abruptly southward since September. Sporadic storm origins over the North Atlantic are associated with short-lived storms. The storms which attain maturity originate over the Bahamas, the west Caribbean, or the eastern Pacific. The large frequency of north or northeastward movement from the point of origin is the distinguishing feature of this chart. The total storm frequency is on the decline.

Figure (9) shows the storm tracks for all other months of these 17 years. It is obvious that the period November-April is outside of the principal tropical cyclone season, and that these storms occur under unusual circumstances.

In the first figure of this presentation, we examined a composite chart for five storms originating in June in the Gulf of Mexico, and noted some characteristics of the flow pattern associated with them. The same composite technique was used to develop the composite sea-level pressure chart for five storms of eastern Pacific origin shown in figure (10). The strengthening of the southeast flow over the Gulf of Mexico and the occurrence of the deep thermal low over Arizona, coupled with a deep trough northward toward Hudson Bay are obvious features of this composite. The 1018 high over New England suggests that these particular eastern North Pacific June origins were coupled with strong anticyclones over the eastern United States. One might speculate--and at this point it would be pure speculation--that these storms originated over the Pacific rather than the Gulf because the patterns favorable to their generation were displaced southward.

Figure (11) shows the composite 500 mb. heights and temperatures associated with the same five eastern Pacific storms. The closed 19,300 ft. high over northern Mexico and southwestern United States with its ridge line extending toward Cuba is displaced southwestward from the position of the comparable pattern in figure (1). The pattern of figure (1) was related to storm genesis in the Gulf of Mexico. These eastern Pacific storms have their origins approximately the same distance southwest of the Gulf origin as the relative displacement of this pattern.

Time does not permit the presentation of similar charts which our group has developed for storms originating in other months of the season and other portions of the oceanic areas, e.g., July storms over the Bahamas; September storms over the western Caribbean, etc., but such composites either have been or are being developed in an empirical search between the geometry of the surface and 500 mb. patterns and storm genesis. At the suggestion of Dr. Harold L. Crutcher and his associates, we are undertaking harmonic analysis of the sea-level pressure and 500 mb. heights along selected latitude circles for data obtained by selecting dates on which storms first appeared at specific values of latitude and longitude.

At the same time that these investigations were underway in Asheville, we were investigating the precipitation associated with tropical storms. Mr. Durham has developed a model of precipitation associated with a unit storm, and we have compared precipitation amounts obtained from storms in each year with the normal variation of precipitable water over a large segment of the northern hemisphere. This investigation is continuing and will be the subject of a separate report.

From this hasty background of relating storm track geometry to synoptic pattern geometry, it is a short step to the question, "How can we use such climatological information as a tropical analysis and forecasting aid?" and the question, "Is this all that climatology can do for us?"

The real purpose of this paper is to propose to this group that there are a number of climatological projects which might be useful in developing tropical analysis and prediction aids. Nine specific proposals are offered here, arranged in a rough order of increasing complexity and cost. Those listed first are simple and inexpensive. The last few are major studies which would involve several man years and major expense to accomplish.

1. <u>Develop monthly mean tropical atmosphere for several sections of the Tropics.</u>

   Monthly means of height, temperature and relative humidity have been computed for West Indies, Central and South American and U. S. stations for available data from 1953-1962.

These tabulated data can be combined to produce monthly mean tropical atmospheres for selected areas.

2. <u>Develop a visual portrayal of the tropical winds aloft summary and parameters.</u>

Wind data and parameters have been summarized and tabulated for a large number of tropical stations by month and atmospheric levels.

Resultant wind direction, speed, vector standard deviation of velocity, zonal components, correlation coefficients, probability ellipses, and multiple related parameters are tabulated at
6. selected millibar levels by month for each station.

The resultant wind and the probability ellipses for several layers of probability can be plotted on charts or on plastic overlays to conform to the charts in use.

It is recommended that the several agencies concerned agree on a standard map projection, family of scales and family of areas of coverage, and that the wind parameter data be printed in a back-
7. ground color on the master base for reproduction on each of the areas and scales.

3. <u>Develop storm movement cases for limited areas stratified by persistence and prior motion.</u>

Most storm movement cases developed so far use as input data the storm position alone. New cases stratified according to 1) storm location, 2) present motion, and 3) past motion, will provide an improvement on the initial climatological storm motion prediction.

4. <u>Develop prediction models for hurricane parameters for wind, pressure, rain, etc., forecasts.</u>

Using representative coastal or low-level reconnaissance data, develop models of the distribution of wind, pressure, precipitation, etc., for selected storms over a range of intensities. These models will be useful in forecasting the distribution of these parameters in relation to prognostic storm positions.

5. Develop a set of data on probability of "storm strikes" in coastal areas for storm situations.

A number of climatological studies have been made of the future path of storms according to present storm location. One specifically designed to prepare probability forecasts of storm threat for specific target areas would be useful.

Utilizing climatological data of storm tracks and stratifying these according to storm position, month, immediate past track, etc., probabilities (in terms of percentage risk of strike) can be developed for specific target areas and time periods.

6. Develop a set of relationships between middle latitude synoptic parameters and tropical storm genesis.

An extension of the work described in this report would provide climatological models of mid-latitude synoptic parameters related to tropical cyclogenesis in selected regions and time periods which would serve as "check list items" for analysts and forecasters.

7. Develop a set of relationships between TIROS cloud patterns and synoptic chart data in tropical cyclone situations.

A catalogue of mosaics of TIROS photographs in tropical cyclone situations can be developed. Surface charts can be reanalyzed for these situations utilizing all available ship observations received by mail (about 3 times as many as by radio). A set of surface and upper air charts can then be reproduced in conjunction with the TIROS mosaics to provide duty forecasters with models useful in the interpretation of new satellite photographs on an operational basis.

8. Develop a set of tropical atmosphere wind shear probability ellipses.

Wind shear is an important parameter in tropical forecasting. Little is known of the climatology of wind shear in the tropical atmosphere.

Utilizing wind data on file, a set of wind shear probability ellipses can be developed for tropical stations portraying the shear distributions through 100 mb. layers (e.g. from

950-850 mb., from 850-750 mb., etc.). These can be plotted on overlays or printed on a map base for comparison with shears plotted on daily synoptic charts and used by forecasters in the early detection of anomalous situations.

9. Develop a set of "normal" surface and upper air charts for the Tropics.

The only level for which reasonably accurate "normal" charts are available in the tropics is the 500 mb. level. This level is suitable for prediction of storm motion but thus far ill-suited for prediction of storm genesis.

Careful plotting of surface charts and development of upper air charts through differential analysis utilizing stability considerations, followed by grid point data readings, would make development of useful normals possible.

The development of such normal charts would be a major undertaking, but might be accomplished over a period of several years by utilizing the capability of the Northern Hemisphere Map Project as this group turns to machine methods for its mid-latitude analysis.

Normals for at least 850 mb., 700 mb. and 200 mb. should be developed.

REFERENCES

1. Cry, G. W., Haggard, W. H., White, H. S. North Atlantic Tropical Cyclones, Technical Paper No. 36, U. S. Weather Bureau, 1959.

2. Davis, O. M. Personal Communication.

3. Rosendal, H. E. "Eastern North Pacific Tropical Cyclones, 1947-1963," Pilot Chart of the North Pacific Ocean, U. S. Weather Bureau, U.S.N. Oceanographic Office, Washington, D. C., April 1964.

4. Climatological Data, National Summary, U. S. Weather Bureau.

5. Bryson, R. A., Henderson, V. C., Horn, L.H., Lahey, J. F., Wahl, E. W., Atlas of 500 Mb. Wind Characteristics for the Northern Hemisphere University of Wisconsin, 1958.